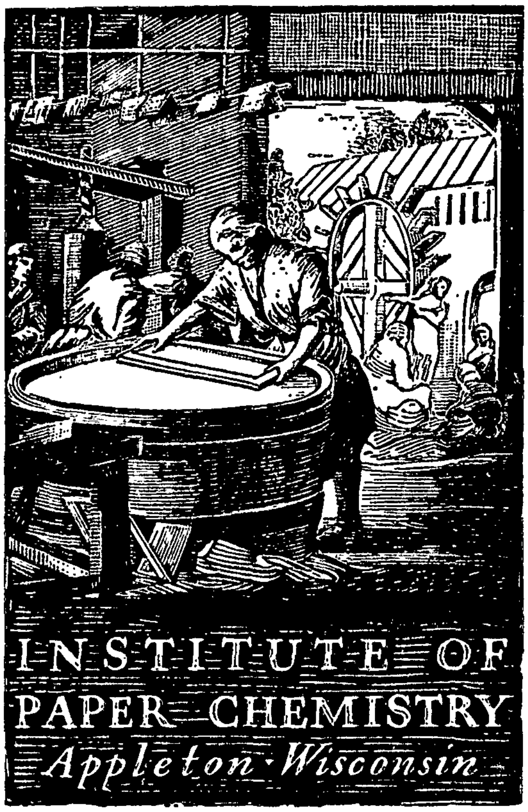


RELATIONSHIP BETWEEN SACK DROP AND SACK PAPER PROPERTIES

PART I. FACE DROP PERFORMANCE

Project 2033

Report Twenty-Nine

A Progress Report

to

MULTIWALL SHIPPING SACK PAPER MANUFACTURERS

February 7, 1964

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

RELATIONSHIP BETWEEN SACK DROP AND SACK PAPER PROPERTIES

PART I. FACE DROP PERFORMANCE

Project 2033

Report Twenty-Nine

A Progress Report

to

MULTIWALL SHIPPING SACK PAPER MANUFACTURERS

February 7, 1964

TABLE OF CONTENTS

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

RELATIONSHIP BETWEEN SACK DROP AND SACK PAPER PROPERTIES

PART I. FACE DROP PERFORMANCE

SUMMARY OF RESULTS

During the past six years a great deal of valuable information and data have been developed in connection with the multiwall sack program, Project 2033. The Policy Committee has requested that, during the present contractual period, one phase of the program be devoted to an analysis and study of the available data so that the information may be utilized in practical applications directed to improvement in sack paper manufacture and sack performance. The underlying objective is to make sack paper cheaper and/or better.

This is the first report in pursuit of the above objective. The analysis was directed to determining the degree to which face drop performance is related to the various sack paper tests at 50% relative humidity. The basis of judging the merits of a given sack paper test was first and foremost the ability of the particular test to predict face drop performance of the sack; however, other factors such as magnitude and sign of the correlation coefficient, general knowledge regarding sack and sack paper behavior, etc., were also considered. It should be mentioned in connection with the selection of tests that the difference in predictive ability between the "best" and the "poorest" test was not much over 10-20%, in most cases. Thus, replacement of the poorest test by the best test would be expected to improve the prediction of sack quality only 10-20%. Where the same test is used for both extensible and flat kraft papers, the spread between the best and the poorest was considerably greater.

For purposes of presentation, the sack paper tests have been classified or grouped according to the predictive ability of each test. Within each group, the tests are arranged in the order of decreasing predictive ability. Analysis

of the data developed in connection with Studies I and II, on pasted sacks relative to the relationship between sack paper properties and face drop performance permit the following conclusions to be drawn. On the flat kraft paper, the predictive ability is the average of Studies I and II.

FLAT KRAFT PAPERS

1. The five best sack paper tests for predicting sack performance (see Fig. 1) are:

a. T.E.A. (tensile energy absorption), combined

b. Stretch, combined

c. Impulse, combined

d. Frag, combined

e. T.A. impact fatigue

2. Based on testing ease, calibration considerations and theoretical concepts, the combined T.E.A. is preferred for specification or control of flat kraft multiwall sack paper.

3. Based on the present results, combined stretch, by itself, appears to offer almost as good predictive ability as T.E.A. which is a function of both tensile and stretch. The relationship involving combined stretch should be viewed with reservation as it is anticipated that this relation may hold only for papers within a given grade weight level. It is well known that stretch is independent of weight and, therefore, if the relationship were applied to various grade weights, it would not be expected to hold, e.g., a sack made with four plies of 60-lb. paper would be expected to outperform a sack made with four plies of 40-lb. paper, but each with the same combined stretch. This indicates that stretch, by itself, is not sufficient except possibly in special cases such as within a given grade weight level.

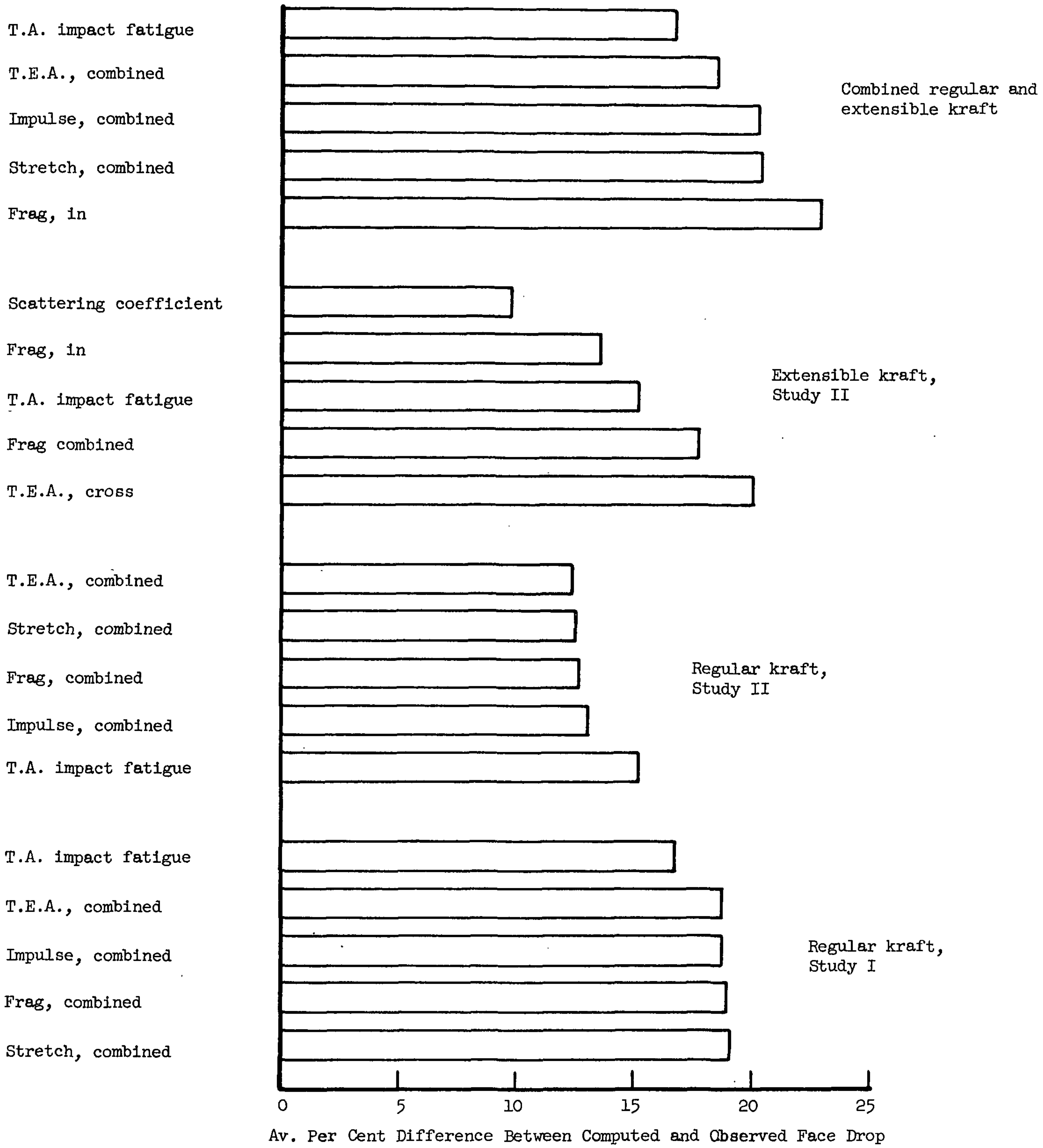


Figure 1. Comparison of Properties Giving the Best Predictions of Face Drop Performance

In contrast to stretch, tensile strength is strongly dependent on weight and, consequently, the tensile will increase as weight increases. As mentioned, the tensile energy absorption (represented by the area under the load-deformation curve) is a function of both stretch and tensile and, therefore, is expected to have more general application. Furthermore, the impact or fatigue tests such as the T.A. impact fatigue and Frag apparently are well related to the initial or virgin T.E.A. characteristics of the paper.

4. Among the paper tests which were found to be less well related (see Fig. 2) to face drop sack performance were bursting strength, tensile, and tearing strength.

EXTENSIBLE SACK PAPERS

The conclusions drawn herein are based on an analysis of the results obtained in Study II.

1. The five best tests for predicting face drop performance of extensible paper sacks (see Fig. 1) arranged in the order of decreasing predictability are:

a. Scattering coefficient

b. Frag, in

c. T.A. impact fatigue

d. Frag, combined

e. T.E.A., cross

2. Although scattering coefficient, Frag and T.A. impact fatigue are better related to face drop performance than T.E.A., cross, it is believed that the latter is more amenable for use in specification, control, etc. The two impact

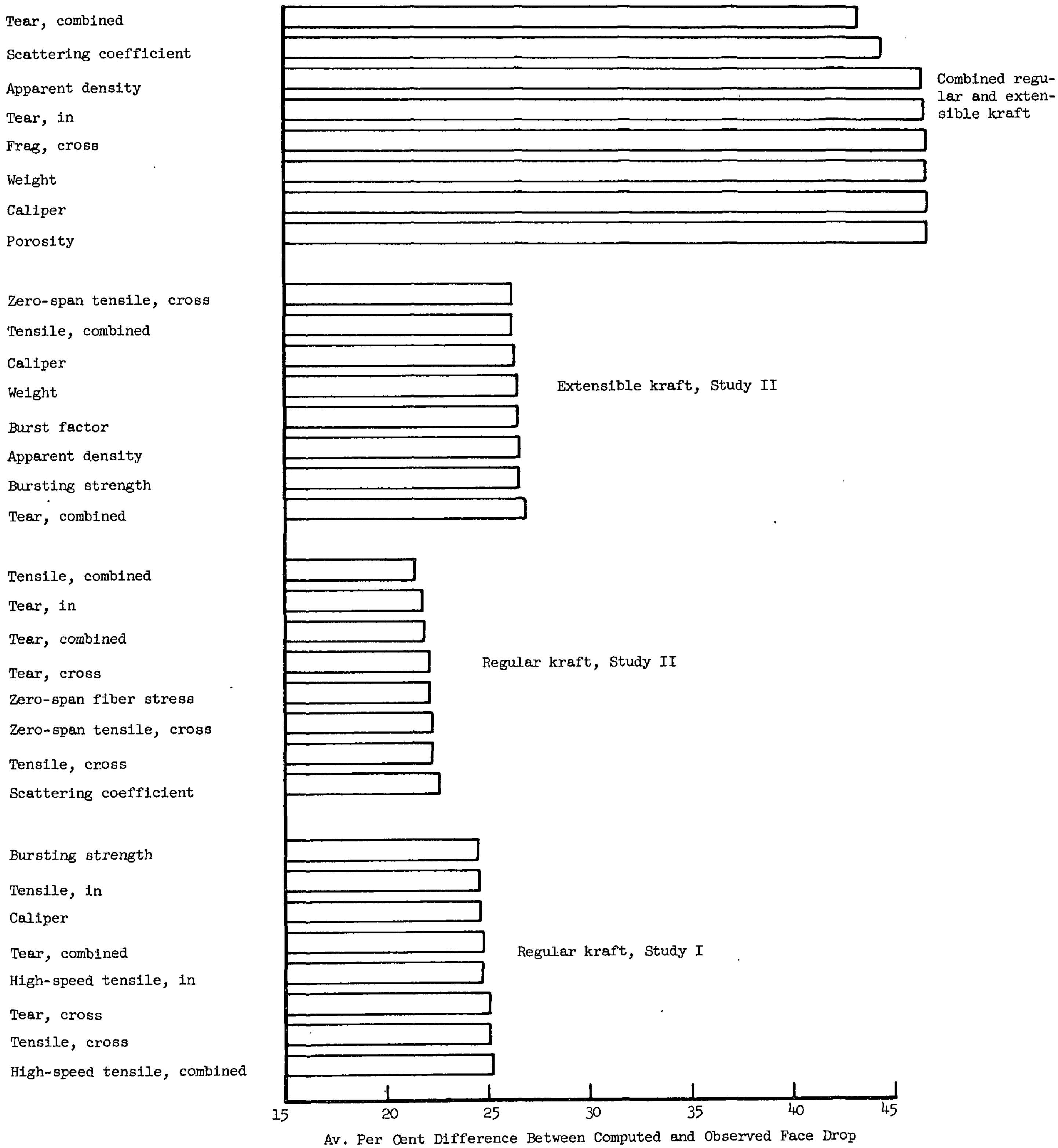


Figure 2. Comparison of Properties Giving the Poorest Predictions of Sack Performance

testers, i.e., Frag and T.A. impact fatigue, are characterized by high variability, long testing time, and little is currently known about the relationship of these tests to the basic properties of sack paper. Although scattering coefficient correlates the best on extensible sack paper, its poor showing on flat kraft, lack of dependency on such things as fiber length, isotropy of the sheet, and relative humidity, raises doubt as to its usefulness as a criterion of quality by itself. It may very well serve a useful role in conjunction with other tests. This concept will be explored more fully in a future report.

3. Among the sack paper tests found to be poorly (see Fig. 2) related to face drop performance were tearing strength, bursting strength, and machine direction tensile. Stretch by itself did not correlate as well with sack performance as was found for the flat kraft sack papers.

EXTENSIBLE AND FLAT SACK PAPERS

When the data were analyzed to determine the most appropriate sack paper tests to be used for both extensible and flat kraft sack paper, the following conclusions were drawn.

1. The five best tests (see Fig. 1) arranged in the order of decreasing predictive ability are:

a. T.A. impact fatigue

b. T.E.A., combined

c. Impulse, combined

d. Stretch, combined

e. Frag, in.

2. Taking test cost, calibration, etc., into account, combined T.E.A. or stretch are recommended for the evaluation of extensible and flat sack kraft paper. Neither T.E.A. nor stretch (nor any of the test properties mentioned) will accurately predict the relative performance of all papers. The use of these tests should, therefore, be tempered by judgment and experience.

GENERAL

The general conclusion derived from the analysis carried out is that at the present time combined T.E.A. is the best test for evaluating paper in terms of face drop performance for flat and extensible sack papers. The use of combined T.E.A. implies that in- and cross-machine T.E.A. are equally important to face drop. This is only an approximation and changes in combined T.E.A. accompanied by large changes in the directional ratio may have unpredictable effects on face drop.

The relationship developed from the data obtained in Studies I and II for three-ply pasted cement size sacks fabricated with flat and extensible sack papers is given by Equation (1) and illustrated in Fig. 3:

$$F = -45.6 + 495.3\ [W_x + W_y] \qquad (1)$$

where $\underline{F}$ = face drop performance at 50% R.H. in safe inches

$\underline{W_x}$, $\underline{W_y}$ = tensile energy absorption (T.E.A.) machine and cross-machine in in. lb./in.^{2}, respectively.

The above equation represents solely an empirical relationship found for three-ply pasted cement sacks tested at 50% R.H. using 94 lb. of cement as the commodity. In addition to paper quality, sack performance is known to vary with type and amount of commodity, dimensions, style, and environmental conditions.

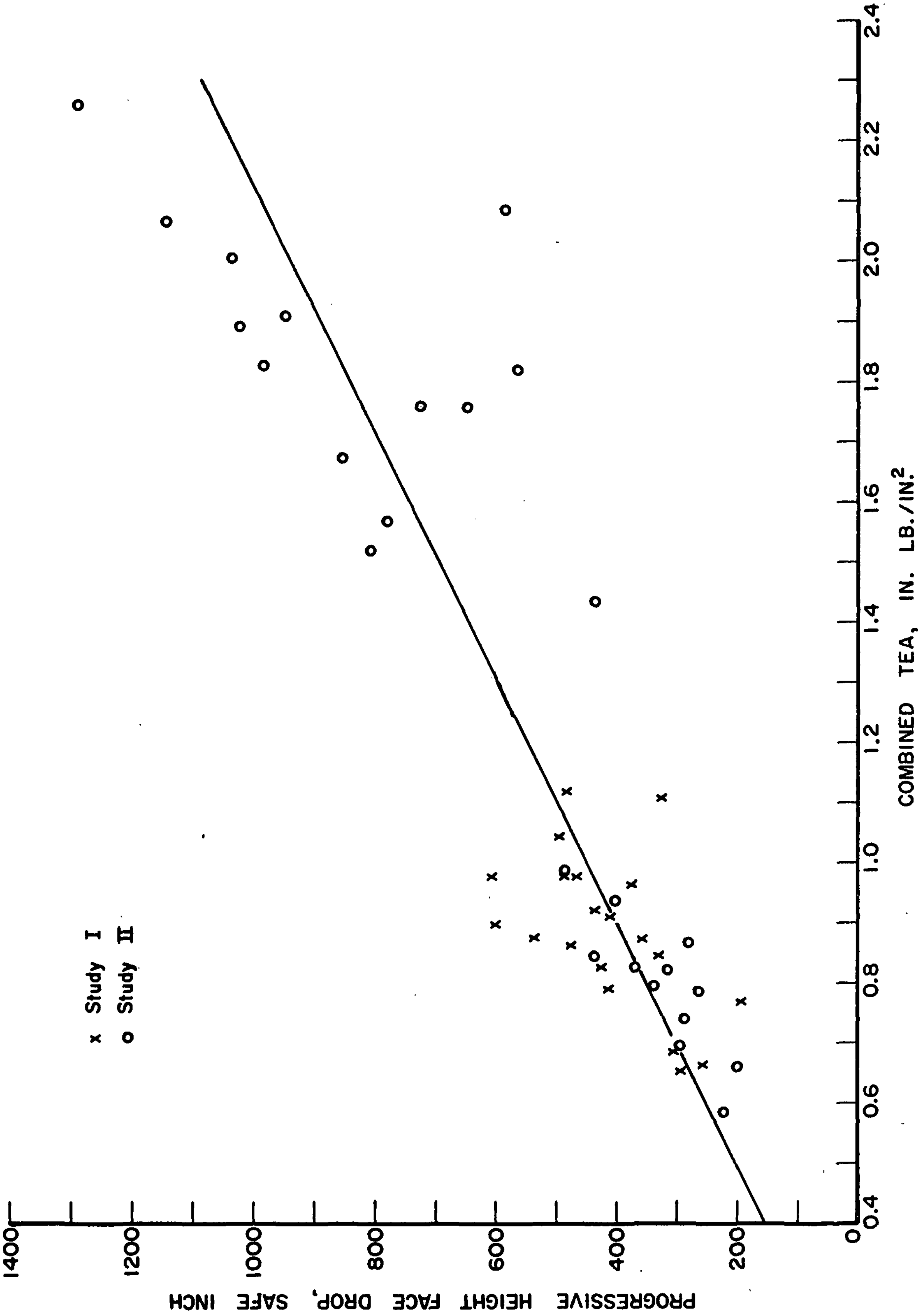
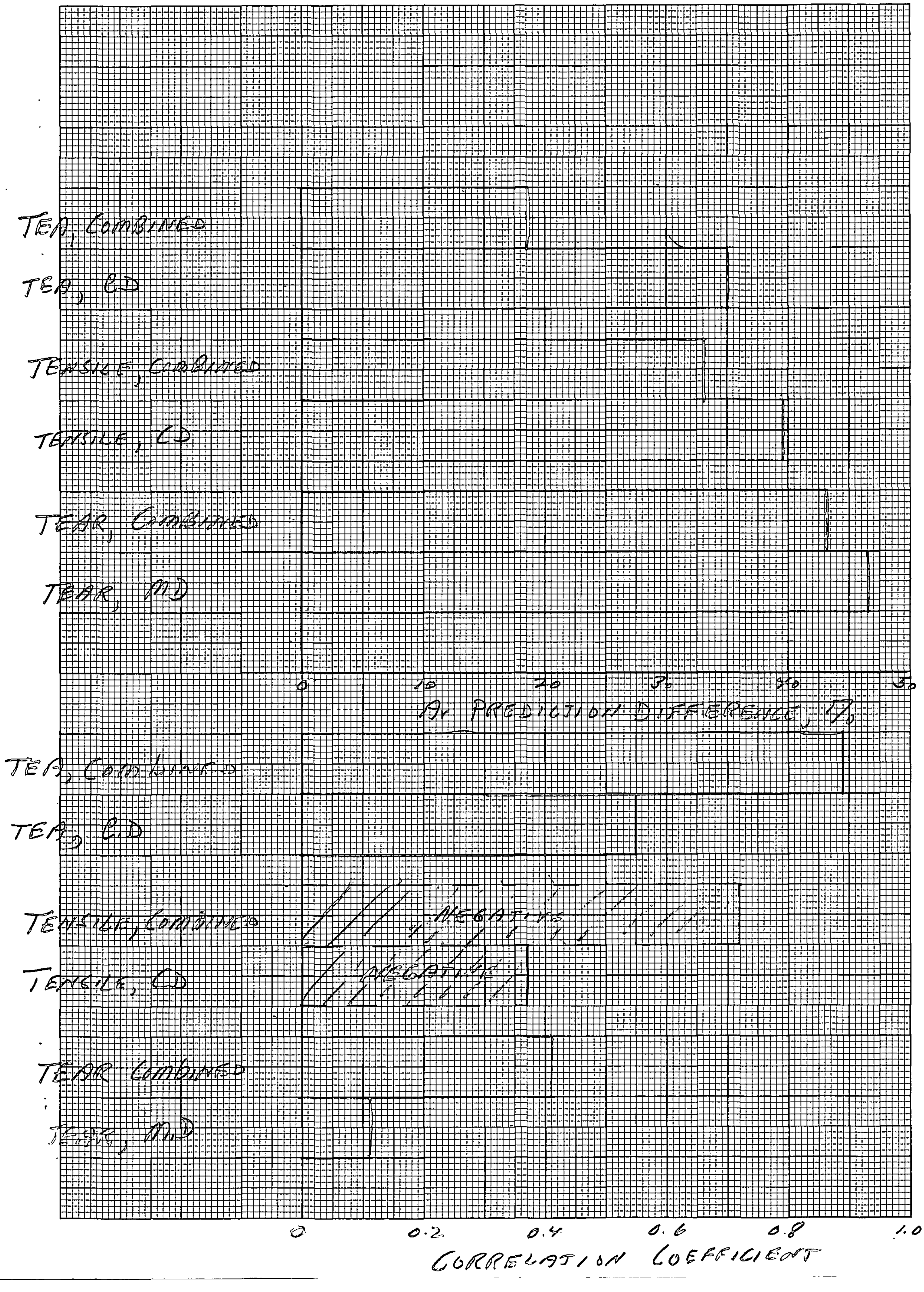


Figure 3. Relationship Between Progressive Height Face Drop and Combined T.E.A. for Three-Ply Pasted Sacks

FACE


TEA, COMBINED
TEA, CD
TENSILE, COMBINED
TENSILE, CD
TEAR, COMBINED
TEAR, MD
0
10
20
30
40
50
PREDICTION DIFFERENCE, %
TEA, COMBINED
TEA, CD
TENSILE, COMBINED
NEGATIVE
TENSILE, CD
NEGATIVE
TEAR COMBINED
TEAR, MD
0
0.2
0.4
0.6
0.8
1.0
CORRELATION COEFFICIENT

Consequently, Equation (1) should not be used for general predictions of face drop sack performance. However, it can be used to predict the effect of changes in T.E.A. on face drop for the conditions employed, and it may be anticipated that such predictions will hold on a relative basis under many conditions.

In order to illustrate the effect which small changes in the T.E.A. characteristics of the sack paper may have on the performance of sacks of the style and size used in this study, sack performance has been calculated using Equation (1). The changes in T.E.A. used in these calculations were those resulting from a change in stretch. The results are tabulated in Table I. It may be noted that a change of approximately 10% in stretch introduced changes in T.E.A. equivalent to about a 17% change in sack performance.

The detailed results associated with this analysis are given in the Appendix. The next two reports will be concerned with (a) sack paper tests which correlate with butt drop performance, and (b) the material and processing variables which influence the paper tests best related to sack performance.

TABLE I

EFFECT OF CHANGES IN T.E.A. ON SACK PERFORMANCE
(Face drop at 50% R.H.)

No.	Change in Stretch, % M.D.	Change in Stretch, % C.D.	T.E.A., in. lb./in.^{2} M.D.	T.E.A., in. lb./in.^{2} C.D.	Combined T.E.A., in.lb./in.^{2}	Sack Performance, safe inches: 50-lb. Flat Kraft	Sack Performance, safe inches: 50-lb. Extensible (1%) Kraft
				Flat kraft paper			
1	+20.4	+19.1	.4417	.618	1.0597	479	---
2	+10.2	+9.6	.3883	.549	.9373	419	---
3	0.0	0.0	.3375	.482	.8195	360	---
4	-10.2	-9.6	.2898	.420	.7098	306	---
5	-20.4	-19.1	.2415	.361	.6025	253	---
6	-30.6	-28.7	.1942	.301	.4952	200	---
				Extensible kraft paper			
7	+10.2	+10.0	1.748	.6927	2.4407	---	1163
8	+5.1	+5.0	1.608	.6535	2.2615	---	1074
9	0.0	0.0	1.478	.6085	2.0865	---	988
10	-5.1	-5.0	1.366	.5595	1.9255	---	908
11	-10.2	-10.0	1.255	.5228	1.7778	---	835

	Flat kraft, 50% RH Study I (N=20) Corr. Coeff.	Flat kraft, 50% RH Study I (N=20) Av. Prediction Diff. %	Flat kraft, 50% RH Study II (N=12) Corr. Coeff.	Flat kraft, 50% RH Study II (N=12) Av. Prediction Diff. %	Extensible kraft, 50% RH Study II (N=14) Corr. Coeff.	Extensible kraft, 50% RH Study II (N=14) Av. Prediction Diff. %	Combined, 50% RH (N=46) Corr. Coeff.	Combined, 50% RH (N=46) Av. Prediction Diff. %	Combined, 10, 25, 50% RH (N=76) Corr. Coeff.	Combined, 10, 25, 50% RH (N=76) Av. Prediction Diff. %
TEA, combined	0.53*	18.7	0.83**	12.3	0.63*	21.6	0.89**	18.4	0.82	
Impulse, "	0.49*	18.7	0.79**	13.0	0.52	24.4	0.87**	20.2	--	
Frag "	0.48*	18.9	0.76**	12.6	0.74**	17.6	0.67**	28.0	--	
T.A. Imp. Fatigue	0.72**	16.7	0.69*	15.2	0.82**	15.1	0.93**	16.7	0.90	
Scatt. Coeff.	-0.33	22.6	-0.16	22.2	-0.91**	9.7	-0.37**	44.3	--	
Frag, In	0.34	21.9	0.56*	17.2	0.83**	13.5	0.87**	22.8	--	
" , Cross	0.47*	19.8	0.80**	12.5	0.36	25.6	-0.08	46.6	--	
Stretch, combined	0.59**	19.0	0.85**	12.5	0.55*	23.1	0.78**	20.3	--	
Tensile, combined									0.56	
Tear, "									0.66	

* Significant at 5% level
** " " " 1% "

APPENDIX I

PROCEDURES

The data for the statistical analyses were taken from the following reports of Project 2033.

Report No.	Report Date
12	February 8, 1960
21	October 1, 1962
22	August 31, 1962
23	October 16, 1962
24	July 22, 1962
25	October 31, 1962

Information on test procedures, etc., may be found in the same reports.

Separate analyses were made for each of the following data subdivisions:

(a) Study I, regular kraft sacks—N = 20

(b) Study II, regular kraft sacks—N = 12

(c) Study II, extensible kraft sacks—N = 14.

Except when specifically noted, the progressive height face drop test results were expressed in safe inches of drop.

Forty-eight properties of the sack paper were evaluated for each study, though in some instances properties were evaluated in one study and not the other. Tests evaluated in only one study included:

1.	Van der Korput energy	Study I only
2.	High-speed tensile	Study I only
3.	High-speed stretch	Study I only
4.	High-speed work	Study I only
5.	Zero-span tensile	Study II only
6.	M.I.T. fold	Study II only
7.	Instron strain fatigue	Study II only
8.	Instron energy fatigue	Study II only

In general, Van der Korput energy and the high-speed tensile, stretch, and work tests correlate well with Instron tests at conventional test rates (1,2). Therefore, tests on the Instron should be an adequate substitute for the Van der Korput or high-speed tests. The remaining tests (5-8 above) were considered to be research tools and undesirable for control or specification purposes. Therefore, they are not considered further in the discussion.

Normally satisfactory conversion is assumed. High failure frequencies in creased areas, in adhesive joints, etc., are not considered in the analysis.

APPENDIX II

ANALYSIS

For this report the simple linear correlations between progressive height face drop and the physical characteristics of the sack paper were reviewed for the two major studies carried out in the past. The statistical correlation summaries are shown in Appendix III, Tables VII through X for the face drop results expressed in safe inches and in Appendix III, Tables XI through XIV for the drop results in safe drops.

Appendix III, Tables XV through XVIII show the test properties arranged in order of their average prediction difference together with the corresponding correlation coefficient. The average prediction difference is the average difference in per cent between computed and observed sack drop values based on the selected sack paper property. These data are graphed in Fig. 3 through 6.

REGULAR SACKS - STUDY I AND II

For the flat kraft sack data graphed in Fig. 4 and 5, the five best properties for predictive purposes are compared in Table II. It may be noted that

1. The correlation coefficients for all five properties were significant at either the 5 or 1% levels.

2. In terms of agreement between predicted and observed face drop values, T.A. impact fatigue ranked first in Study I and T.E.A., combined ranked first in Study II.

3. The greater variance of the fatigue tests (Frag and T.A. impact fatigue) makes it desirable to evaluate a relatively large number of specimens to achieve reasonable precision. Therefore, the long evaluation times required make these tests ill adapted for control or specification purposes.

TABLE II

COMPARISON OF THE FIVE PROPERTIES GIVING THE BEST PREDICTIONS OF FACE DROP PERFORMANCE FOR THE REGULAR SACKS OF STUDIES I AND II

	T.A. Impact Fatigue Study I	T.A. Impact Fatigue Study II	TEA, combined Study I	TEA, combined Study II	Impulse, combined Study I	Impulse, combined Study II	Frag, combined[g] Study I	Frag, combined[g] Study II	Stretch, combined Study I	Stretch, combined Study II
Type of test	Const. ht. fatigue		Tensile energy		High rate tensile		Const. ht. fatigue		Ultimate stretch	
Av. prediction diff, %	16.7	15.2	18.7	12.3	18.7	13.0	18.9	12.6	19.0	12.5
Correlation coefficient	0.72[a]	0.69[b]	0.53[b]	0.83[a]	0.49[b]	0.79[a]	0.48[b]	0.76[a]	0.59[a]	0.85[a]
Regression constants										
Intercept	166.3	201.5	22.7	-175.0	-22.1	-447.0	149.5	1.9	49.1	-251.6
Slope	10.9	7.78	442	629.0	25.2	51.1	0.264	0.374	67.4	119.2
Representative test value	23	16	0.884	0.794	17	15.1	999[c]	863	5.4	4.8
Units	falls	falls		in.lb./in.^{2}	mNs.	mNs.	10^{-4}kg. m.	10^{-4}kg. m.	%	%
Percentage change in property to effect a 10% change in drop test performance[f]	17	19	11	17	9	5	16	10	11	6
Test variability										
Standard deviation, %										
Nondirectional	40		--		--		--		--	
In	--		17		18		10(30)[d]		10	
Cross	--		18		29		6(19)[d]		16	
No. of tests to reduce standard error to 5%										
Nondirectional	64		--		--		--		--	
In	--		12		12		36[e]		4	
Cross	--		12		34		15[e]		10	
Impact rate (fatigue tests)	30 per minute						25 per minute			

[a]Significant at 0.1 level.
[b]Significant at 0.5 level.
[c]Average in machine burst energy was 403 kg. m.x 10^{-4} corresponding to approximately 24 falls to failure. Average cross machine burst energy was 596 kg. m.x 10^{-4} or approximately 77 falls to failure using a 14-cm. drop height and 100-gram load. For a 14-cm. height and 200-gram load the falls to failure would be estimated at about 3 and 10 for the in and cross directions, respectively.
[d]The value in parentheses is the per cent standard deviation in terms of falls to failure.
[e]Estimated from the per cent standard deviations in falls to failure using a 14-cm. height and 100-gram load.
[f]Calculated for a 10% change at a level of 414 safe inches.
[g]In Study II cross-machine Frag gave equally good predictions as combined Frag; however, in Study I the better predictions were obtained with combined Frag.

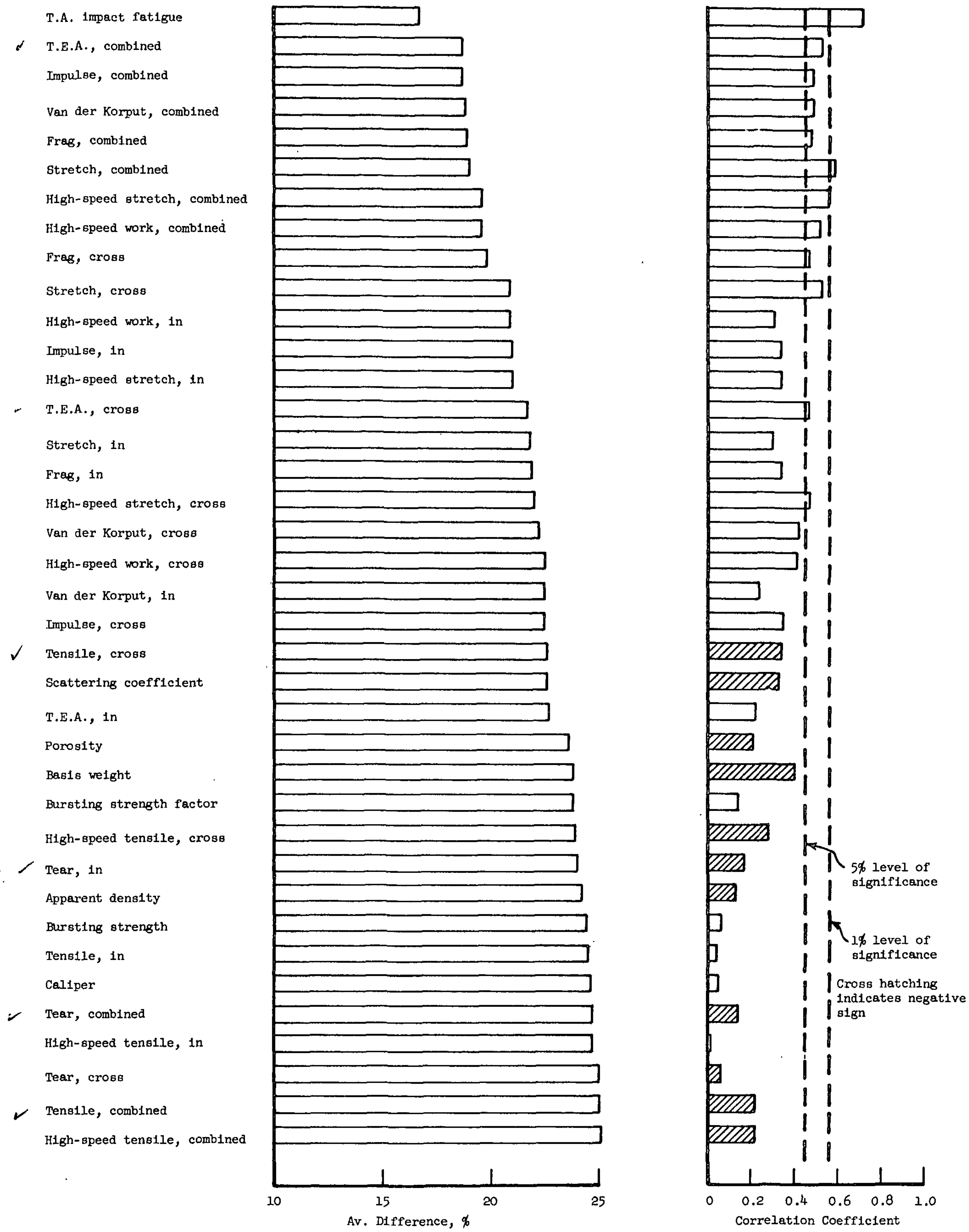


Figure 4. Comparative Ranking of Sack Paper Properties Based on Face Drop Predictive Ability for Regular Kraft Materials from Study I

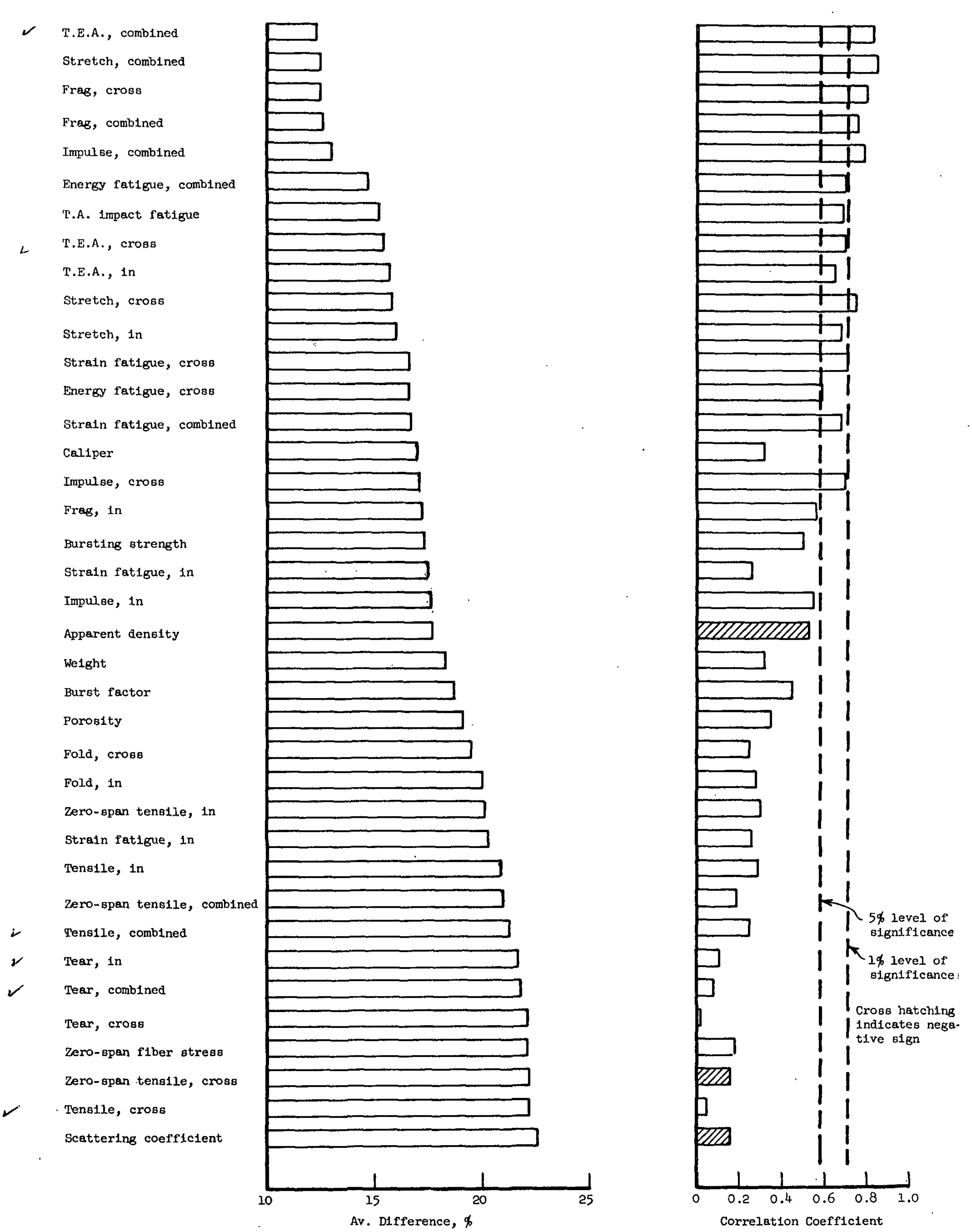


Figure 5. Comparative Ranking of Sack Paper Properties Based on Face Drop Predictive Ability for Regular Kraft Materials from Study II

4. On this basis, the properties listed below exhibit greatest promise as indicators of regular kraft sack performance.

(a) T.E.A., combined
(b) Impulse, combined
(c) Stretch, combined

T.E.A. is dependent on the ultimate tensile strength, stretch, and shape of the load elongation curve. For a given flat kraft sheet weight, T.E.A. appears to be more dependent on stretch than tensile (1,2). Its favorable relationship to face drop appears reasonable if (a) it is accepted that the sack walls absorb tensile energy on each impact, and (b) that failure occurs when the energy input to the sack walls is locally greater than their ability to absorb energy. T.E.A. is also related to moisture content in much the same way as face drop although discrepancies may occur at high humidities (3).

The favorable relationship of combined stretch is also believed to be due to the requirement that the sack paper absorb energy during impact. Apparently, for a given grade weight, increases in stretch are usually accompanied by increases in T.E.A. because of the shape of the load-elongation curves. Conversely, increases in tensile are not necessarily associated with an increase in T.E.A. — apparently because they are usually obtained at the expense of stretch. The higher intercorrelations between T.E.A. and stretch bear this out (1,2). However, over a range of grade weights it would be necessary to consider both stretch and tensile.

The impulse test is a high-speed test which integrates the force transmitted through a tensile strip over the period of time to break. It is similar to T.E.A. and is highly correlated to T.E.A. (1,2) at 50% R.H. It also varies with moisture content in the same manner as face drop. Its main advantage lies in its high test rate. Its main disadvantages include (a) possible misalignment and parts breakage (1), (b) its narrow specimen (0.4 cm.) which may be sensitive to edge effects, and (c) its low range - some extensible samples give values above the scale range. In addition, it is believed that few companies in the industry have incorporated it in their test facilities.

The Frag test involves the repeated impact from a constant height of a charge of small pellets against a specimen stretched over a circular orifice. The specimen is rectangular and clamped along two opposite sides. To avoid extremely long test times, the manufacturer recommends varying the height or load to give a reasonable number of impacts to failure. Results at different heights or load are converted to a common basis by multiplying the load and height used by the cube root of the drop number, although the procedure is questionable (4). As a fatigue test, the Frag simulates the fatigue nature of the sack drop test. The results depend on specimen orientation. Important biaxial strains are induced in the specimen (2) so that failure may be influenced by the directional ratios of the specimen. As a fatigue test, it is characterized by high test variability, somewhat masked by the cube root factor for number of drops. Frag results pass through a maximum at about 50% R.H. (3). As humidity decreases from 50% R.H. the results drop off sharply, in the same manner as sack drop. At humidities greater than 50%, Frag results tend to decrease slowly (regular kraft) or appreciably (extensible kraft). Frag results do not, therefore, predict the observed increases in sack performance above 50% R.H. Mechanically, the machine used at The Institute of Paper Chemistry has been weak and inter- or intralaboratory calibration would be difficult. Other investigators have noted similar problems (5).

Thwing-Albert (Couch-Muldoon) impact fatigue involves the repeated impact of steel balls on the central region of a specimen stretched over a circular orifice. As a fatigue test it simulates the fatigue nature of the drop test. Each impact locally strains the specimen biaxially — an advantage for face drop simulation which also involves biaxial strains. This is a disadvantage for butt drop. Besides suffering from high test variability, comparison of sheets having widely different fatigue strengths may involve inordinate amounts of testing.

Taking these factors into consideration, it appears that combined T.E.A. is the most favorable property for specification or control purposes. It is obvious, however, that it can fail to satisfactorily predict the performance of some sack paper combinations.

Properties exhibiting the least predictive ability for face drop regular kraft sacks were as follows:

	Study I			Study II		
	Property	Corr. Coeff.	Av. Prediction Diff., %	Property	Corr. Coeff.	Av. Prediction Diff., %
1.	Bursting strength	0.06	24.4	Tensile, combined	0.25	21.3
2.	Tensile, in	0.04	24.5	Tear, in	0.11	21.7
3.	Caliper	0.05	24.6	Tear, combined	0.08	21.8
4.	Tear, combined	-0.14	24.7	Tear, cross	0.02	22.1
5.	High-speed tensile, in	0.01	24.7	Zero-span stress	0.18	22.1
6.	Tear, cross	-0.06	25.0	Zero span, cross	-0.16	22.2
7.	Tensile, cross	-0.22	25.0	Tensile, cross	0.05	22.2
8.	High-speed tensile, combined	-0.22	25.1	Scattering coeff.	-0.16	22.6

Within a given grade weight both tensile and tear show no relationship to face drop performance.

EXTENSIBLE SACK PERFORMANCE – STUDY II

Figure 6 shows the ranking of the various physical characteristics of the sack paper for the extensible papers of Study II. Disregarding those properties not evaluated in both studies, the five best properties for predictive purposes were as shown in Table III.

TABLE III

PROPERTIES EXHIBITING THE BEST PREDICTIONS OF THE FACE DROP PERFORMANCE OF EXTENSIBLE SACKS

	Property	Corr. Coeff.[a]	Av. Prediction Diff., %
1.	Scattering coefficient	-0.91	9.7
2.	Frag, in	0.83	13.5
3.	T.A. impact fatigue	0.82	15.1
4.	Frag, combined	0.74	17.6
5.	T.E.A., cross	0.66	20.0

[a]Significant at the 1% level.

In general, the scattering coefficient gave appreciably better predictions of the performance of the extensible sacks than the other properties. The fatigue properties, in machine Frag, T.A. impact fatigue, and combined Frag, followed in that order. Combined T.E.A. and Impulse fell out of the first five though both exhibited significant correlations.

Scattering coefficient is a measure of the unbonded area and, consequently, is indirectly related to the bonded area. The bonded area is one of the basic factors in sheet strength and has been shown to be one of the main factors in tensile strength. Therefore, its favorable relationship to sack performance is physically understandable. While not usually considered suitable for specification, as a nondestructive property it could be useful in automatic control applications.

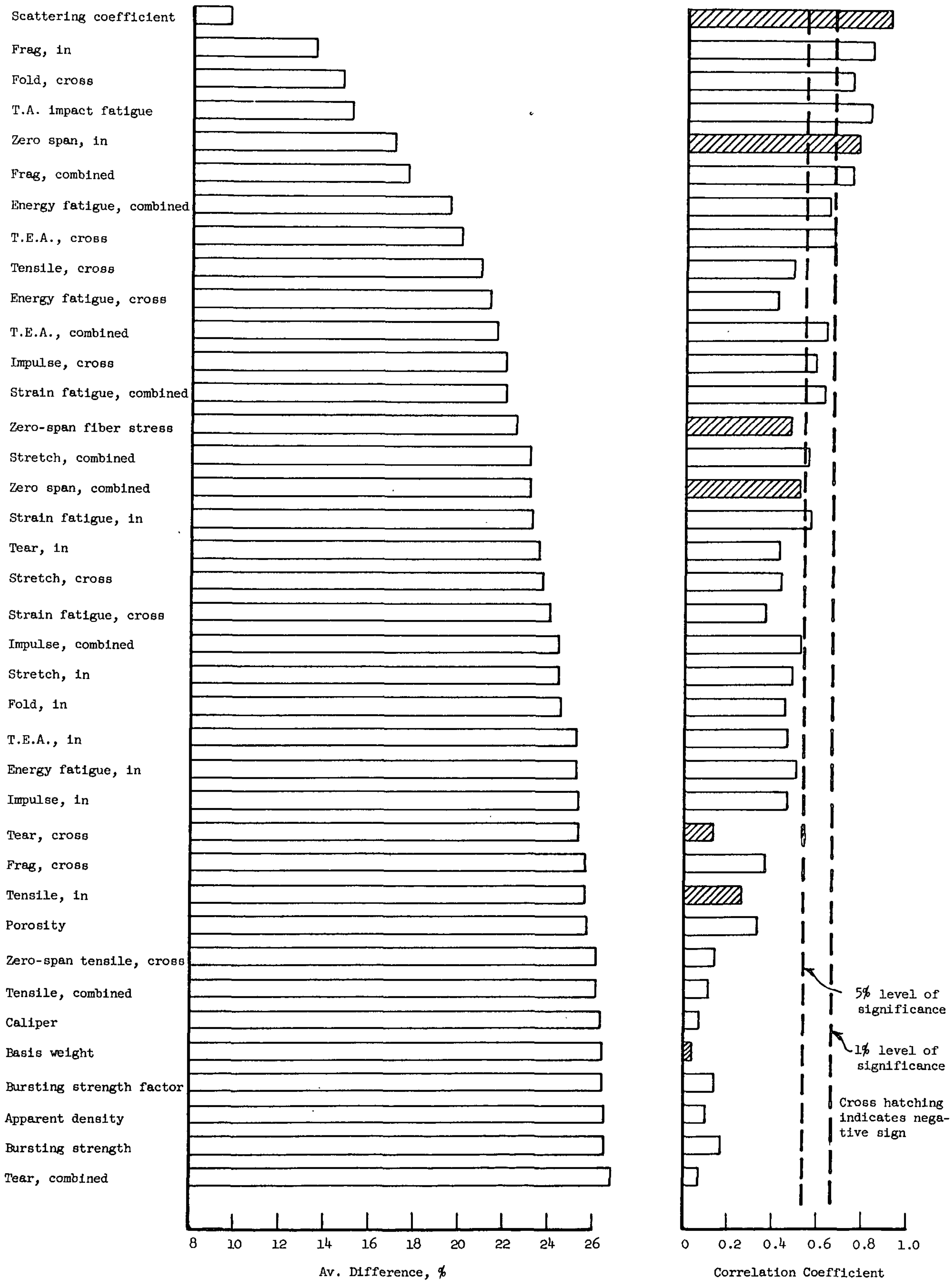


Figure 6. Comparative Ranking of Sack Paper Properties Based on Face Drop Predictive Ability for Extensible Kraft Materials from Study II

T.A. impact fatigue and Frag offer the same advantages and disadvantages as previously discussed.

Therefore, if the fatigue tests are considered unsuitable for control or specifications, the properties giving the more favorable predictions of extensible sack performance are (1) scattering coefficient, and (2) T.E.A., cross.

The properties giving the poorer predictions of extensible sack performance are shown in Table IV.

TABLE IV

PROPERTIES GIVING POOREST PREDICTIONS OF EXTENSIBLE SACK PERFORMANCE

	Property	Corr. Coeff.	Av. Prediction Diff., %
1.	Zero span, cross	0.14	26.1
2.	Tensile, combined	0.11	26.1
3.	Caliper	-0.07	26.3
4.	Weight	0.04	26.4
5.	Burst factor	0.14	26.4
6.	Apparent density	0.10	26.5
7.	Bursting strength	0.17	26.5
8.	Tear, combined	0.07	26.8

Both combined tear and tensile were included among the properties giving the poorest predictions of sack performance.

COMBINED REGULAR AND EXTENSIBLE DATA

For the regular and extensible sack data, the correlations and prediction percentage differences are illustrated in Fig. 7. Because of the greater range covered by the combined data, many properties exhibited highly significant correlations. The five best properties in terms of face drop prediction are shown in Table V.

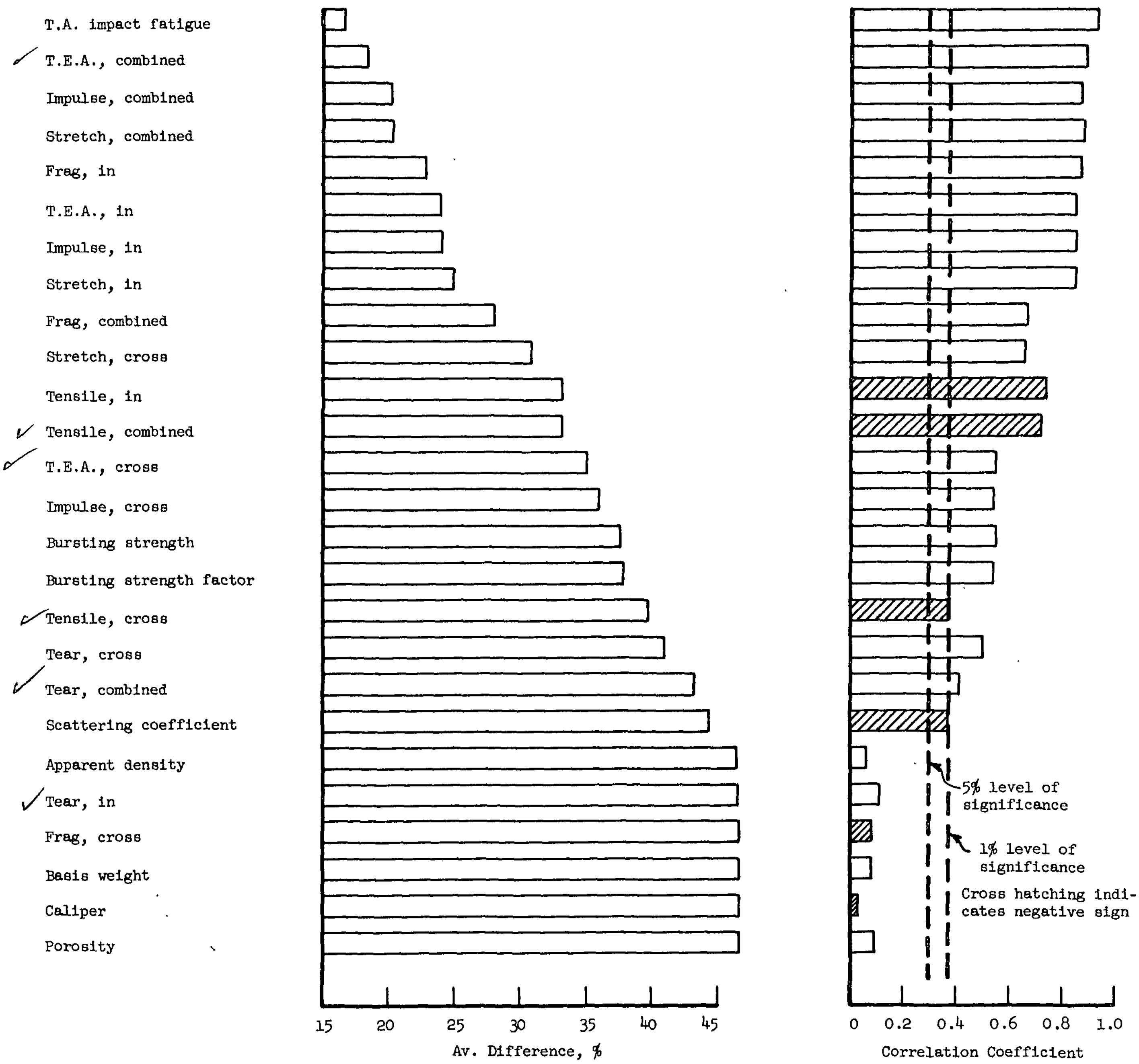


Figure 7. Comparative Ranking of Sack Paper Properties Based on Face Drop Predictive Ability for Regular and Extensible Kraft Materials

TABLE V

PROPERTIES EXHIBITING THE BEST PREDICTIONS OF FACE DROP PERFORMANCE FOR THE COMBINED REGULAR AND EXTENSIBLE DATA

Property	Corr. Coeff.[a]	Av. Prediction Diff., %
1. T.A. impact fatigue	0.93	16.7
2. T.E.A., combined	0.89	18.4
3. Impulse, combined	0.87	20.2
4. Stretch, combined	0.88	20.3
5. Frag, in	0.87	22.8

[a]Significant at 1% level.

The properties in Table V are the same as those listed for the regular sack data alone, except for the substitution of in-machine Frag for the combined Frag.

A comparative ranking of the better properties for face drop sack prediction is shown in Table VI. On an over-all basis the data indicate that properties giving the best prediction of face drop sack performance are as follows:

1. T.A. impact fatigue
2. T.E.A., combined
3. Frag, combined
4. Stretch, combined
5. Impulse, combined

When the Frag and T.A. impact fatigue properties are discarded because of their high variability and time-consuming nature, the best properties for face drop prediction of both regular and extensible sacks are combined T.E.A., stretch, and impulse.

These properties were discussed in connection with the regular kraft sack results. These properties inherently involve energy absorption capacity, a factor which is probably important to face drop behavior.

TABLE VI

COMPARATIVE RANKING OF PROPERTIES WITH REGARD TO FACE DROP SACK PREDICTION

	Property	Rank[a] Regular Sacks Study I	Study II	Extensible Sacks	Combined Data	Composite Rank
1.	T.A. impact fatigue	1	7	4	1	13
2.	T.E.A., combined	2.5	1	11	2	16.5
3.	Impulse, combined	2.5	5	21	3	31.5
4.	Stretch, combined	5	2	15	4	26
5.	Frag, in	16	17	2	5	40
6.	Frag, combined	4	4	6	9	23
7.	Scattering coefficient	22.5	38	1	20	81.5
8.	T.E.A., cross	14	8	8	13	43
9.	Frag, cross	9	3	28.5	25	65.5

[a]Based on average percentage prediction difference.

In each case the sum of in and cross directions is involved. This appears reasonable since the sack is stressed in both directions in a face drop.

In the analysis, both in and cross directions are assigned equal weight. This is considered an approximation since it is believed that the proper weighting depends on both the sack paper and sack dimensions.

The regression equations for the combined data are given below:

1. T.E.A., combined: $\underline{F} = -45.6 + 495.3\ [\underline{W}_x + \underline{W}_y]$ (1)

2. Stretch, combined: $\underline{F} = 88.6 + 55.4\ [\underline{S}_x + \underline{S}_y]$ (2)

3. Impulse, combined: $\underline{F} = -70.4 + 27.5\ [\underline{I}_x + \underline{I}_y]$ (3)

where $\underline{F}$ = progressive height face drop, safe inch.

$\underline{W}_x$, $\underline{W}_y$ = T.E.A., in and cross

$\underline{S}_x$, $\underline{S}_y$ = stretch, in and cross

$\underline{I}_x$, $\underline{I}_y$ = Impulse, in and cross

To improve face drop sack performance by 10% at a level of 400 safe inches, Equations (1), (2), and (3) imply that the combined T.E.A. must be increased by about 9%, combined stretch by 13 or combined Impulse by 12%.

APPENDIX III

CORRELATION TABLES

TABLE VII

LINEAR RELATIONSHIPS BETWEEN SACK PAPER PROPERTIES AND PROGRESSIVE HEIGHT FACE DROP IN SAFE INCHES

Study I – 20 Regular Kraft Samples

Variable	Regression Constants: Intercept	Regression Constants: Slope[a]	Correlation Coefficient	Av. Diff., %[b]	Per Cent of Comparisons Within: ±10%	±15%	±25%
Weight	2549.7	-41.69(22.8)	-0.40	23.8	25.0	40.0	75.0
Caliper	344.5	12.56(57.3)	0.05	24.6	30.0	40.0	65.0
Apparent density	577.7	-17.54(30.7)	-0.13	24.2	35.0	45.0	65.0
Bursting strength	355.1	1.487	0.06	24.4	30.0	50.0	65.0
Bursting strength factor	273.0	182.9	0.14	23.8	35.0	50.0	65.0
Tearing strength, in	652.6	-1.940	-0.17	24.0	30.0	50.0	60.0
cross	489.0	-0.5742	-0.06	25.0	20.0	45.0	60.0
combined	639.7	-0.8877	-0.14	24.7	15.0	50.0	65.0
Tensile, in	350.8	1.866(10.7)	0.04	24.5	30.0	45.0	65.0
cross	703.2	-15.10(9.95)	-0.34	22.6	40.0	55.0	70.0
combined	797.5	-7.265	-0.22	25.0	20.0	40.0	70.0
Stretch, in	182.6	143.0	0.30	21.8	45.0	60.0	60.0
cross	181.7	61.18	0.53	20.9	35.0	45.0	70.0
combined	49.1	67.43	0.59	19.0	35.0	45.0	75.0
T.E.A., in	289.4	350.3	0.22	22.7	45.0	60.0	65.0
cross	177.9	444.8	0.47	21.7	25.0	50.0	75.0
combined	22.7	442.0	0.53	18.7	45.0	55.0	80.0
Frag, in	250.4	0.4047	0.34	21.9	45.0	55.0	70.0
cross	175.1	0.3998	0.47	19.8	30.0	60.0	75.0
combined	149.5	0.2642	0.48	18.9	50.0	65.0	80.0
Impulse, in	197.5	26.20	0.34	21.0	55.0	55.0	65.0
cross	203.0	23.27	0.35	22.5	30.0	40.0	65.0
combined	-22.1	25.19	0.49	18.7	45.0	55.0	75.0
T.A. impact fatigue	166.3	10.90	0.72	16.7	40.0	65.0	75.0
Porosity	440.2	-2.012	-0.21	23.6	35.0	45.0	65.0
Scattering coefficient	821.0	-1.653(1.12)	-0.33	22.6	35.0	40.0	65.0
Van der Korput energy, in	294.0	62.64(59.5)	0.24	22.5	45.0	60.0	60.0
cross	192.8	87.29(43.9)	0.42	22.2	35.0	45.0	60.0
combined	54.5	80.90(33.8)	0.49	18.8	35.0	60.0	75.0
High-speed tensile, in	392.6	0.7460(16.4)	0.01	24.7	25.0	40.0	65.0
cross	665.5	-13.88(11.4)	-0.28	23.9	20.0	40.0	70.0
combined	824.2	-8.871(9.38)	-0.22	25.1	20.0	30.0	55.0
High-speed stretch, in	97.9	189.0(123.5)	0.34	21.3	45.0	60.0	60.0
cross	177.8	70.80(31.7)	0.47	22.0	20.0	45.0	75.0
combined	-18.5	86.43(29.8)	0.56	19.6	40.0	50.0	75.0
High-speed work, in	197.0	603.3(443)	0.31	20.9	50.0	60.0	65.0
cross	181.8	462.3(244)	0.41	22.5	25.0	50.0	60.0
combined	-34.1	520.3(203)	0.52	19.6	35.0	50.0	75.0

[a]Parentheses: Standard error of slope.

[b]Based on observed value as reference.

TABLE VIII

LINEAR RELATIONSHIPS BETWEEN SACK PAPER PROPERTIES AND PROGRESSIVE HEIGHT FACE DROP IN SAFE INCHES

Study II — 12 Regular Samples

Variable	Regression Constants: Intercept	Regression Constants: Slope[a]	Correlation Coefficient	Av. Diff., %[b]	Per Cent of Comparisons Within ±10%	±15%	±25%
Weight	-1260.9	31.07(28.8)	0.32	18.3	33.3	50.0	75.0
Caliper	-233.5	92.53(45.8)	0.54	17.0	58.3	58.3	75.0
Apparent density	891.2	-66.52(33.9)	-0.53	17.7	58.3	58.3	83.3
Bursting strength	-118.3	11.51	0.50	17.3	41.7	50.0	75.0
Bursting strength factor	-70.2	523.6	0.45	18.7	33.3	50.0	66.7
Tearing strength, in	217.7	0.8724	0.11	21.7	33.3	50.0	75.0
cross	288.7	0.2768	0.02	22.1	16.7	50.0	75.0
combined	225.0	0.3945	0.08	21.8	16.7	50.0	75.0
Tensile, in	71.0	7.590(7.97)	0.29	20.9	33.3	41.7	58.3
cross	281.3	2.290(14.3)	0.05	22.2	16.7	41.7	58.3
combined	50.4	5.235	0.25	21.3	25.0	33.3	66.7
Stretch, in	-234.1	370.5	0.68	16.0	41.7	50.0	75.0
cross	-60.9	116.0	0.75	15.8	33.3	41.7	83.3
combined	-251.6	119.2	0.85	12.5	41.7	66.7	100.0
T.E.A., in	-19.1	1047	0.65	15.7	41.7	66.7	83.3
cross	-1.4	699.8	0.70	15.4	25.0	58.3	83.3
combined	-175.0	629.0	0.83	12.3	50.0	66.7	91.7
Frag, in	141.7	0.4830	0.56	17.2	50.0	58.3	75.0
cross	-26.1	0.7252	0.80	12.5	50.0	58.3	91.7
combined	1.9	0.3742	0.76	12.6	50.0	66.7	83.3
Impulse, in	-153.0	61.85	0.55	17.6	41.7	50.0	75.0
cross	-170.5	67.07	0.70	17.1	25.0	58.3	75.0
combined	-447.0	51.08	0.79	13.0	50.0	66.7	83.3
T.A. impact fatigue	201.5	7.781	0.69	15.2	50.0	58.3	75.0
Porosity	262.8	7.009	0.35	19.1	41.7	41.7	66.7
Scattering coefficient	627.5	-1.217(2.41)	-0.16	22.6	16.7	33.3	58.3
Zero-span tensile, in	-86.7	5.782(5.78)	0.30	20.1	25.0	50.0	58.3
cross	636.1	-5.469(10.4)	-0.16	22.2	25.0	41.7	66.7
combined	-103.8	3.346(5.46)	0.19	21.0	16.7	50.0	75.0
Zero-span fiber stress	-99.1	7.479(12.6)	0.18	22.1	16.7	41.7	75.0
M.I.T. fold, in	238.8	0.1802(0.197)	0.28	20.0	33.3	58.3	75.0
cross	229.0	0.2179(0.269)	0.25	19.5	33.3	50.0	75.0
Instron strain fatigue, in	169.1	40.78(48.7)	0.26	20.3	33.3	33.3	75.0
cross	-100.2	95.49(29.8)	0.71	16.6	8.3	50.0	83.3
total	-223.7	66.34(22.8)	0.68	16.7	41.7	41.7	75.0
Instron energy fatigue, in	135.6	33.63(15.8)	0.56	17.5	41.7	50.0	75.0
cross	18.2	56.42(24.1)	0.59	16.6	16.7	41.7	75.0
total	-25.3	31.66(10.2)	0.70	14.7	50.0	50.0	83.3

[a] Parentheses: Standard error of slope.
[b] Based on observed value as reference.

TABLE IX

LINEAR RELATIONSHIPS BETWEEN SACK PAPER PROPERTIES AND PROGRESSIVE HEIGHT FACE DROP IN SAFE INCHES

Study II — 14 Extensible Samples

Variable	Regression Constants		Correlation Coefficient	Av. Diff., %[b]	Per Cent of Comparisons Within		
	Intercept	Slope[a]			±10%	±15%	±25%
Weight	442.5	7.836(54.5)	0.04	26.4	21.4	35.7	64.3
Caliper	978.1	-23.24(89.6)	-0.07	26.3	28.6	35.7	57.1
Apparent density	577.0	29.43(80.5)	0.10	26.5	28.6	35.7	57.1
Bursting strength	406.5	9.724	0.17	26.5	14.3	35.7	57.1
Bursting strength factor	513.4	378.0	0.14	26.4	14.3	42.9	57.1
Tearing strength, in	-1017.1	15.00	0.42	23.5	21.4	42.9	64.3
cross	1220.7	-2.481	-0.13	25.3	35.7	42.9	64.3
combined	603.9	0.8778	0.07	26.8	21.4	28.6	57.1
Tensile, in	1407.6	-26.48(28.8)	-0.26	25.6	21.4	28.6	57.1
cross	-141.6	60.38(32.1)	0.48	20.9	35.7	42.9	64.3
combined	502.8	9.126	0.11	26.1	21.4	42.9	64.3
Stretch, in	309.3	58.35	0.48	24.4	14.3	28.6	71.4
cross	-168.8	218.5	0.43	23.7	35.7	42.9	71.4
combined	-23.0	62.78	0.55	23.1	14.3	28.6	71.4
T.E.A., in	145.4	562.6	0.46	25.2	21.4	42.9	71.4
cross	-244.6	1893	0.66	20.0	21.4	42.9	71.4
combined	-348.8	656.1	0.63	21.6	14.3	64.3	78.6
Frag, in	-388.5	1.768	0.83	13.5	35.7	64.3	92.9
cross	300.7	1.212	0.36	25.6	7.1	21.4	64.3
combined	-394.6	1.081	0.74	17.6	21.4	35.7	85.7
Impulse, in	287.8	23.67	0.46	25.3	14.3	50.0	71.4
cross	-305.2	120.1	0.58	22.0	14.3	42.9	78.6
combined	94.1	22.67	0.52	24.4	14.3	42.9	64.3
T.A. impact fatigue	50.7	14.60	0.82	15.1	42.9	57.1	71.4
Porosity	681.1	13.31	0.33	25.7	35.7	35.7	64.3
Scattering coefficient	3956.7	-12.73(1.66)	-0.91	9.7	42.9	78.6	100.0
Zero-span tensile, in	2957.6	-39.45(9.34)	-0.77	17.0	42.9	57.1	78.6
cross	412.6	8.514(17.2)	0.14	26.1	28.6	42.9	64.3
combined	2990.6	-20.56(9.97)	-0.51	23.1	28.6	50.0	78.6
Zero-span fiber stress	2691.9	-40.26(21.7)	-0.47	22.5	28.6	50.0	64.3
M.I.T. fold, in	426.1	0.6149(0.356)	0.45	24.5	14.3	35.7	64.3
cross	176.9	1.734(0.460)	0.74	14.7	35.7	57.1	92.9
Instron strain fatigue, in	-180.3	75.28(32.4)	0.56	23.2	21.4	35.7	64.3
cross	-34.8	148.0(112)	0.36	24.0	35.7	50.0	64.3
total	-674.1	77.62(28.3)	0.62	22.0	14.3	42.9	64.3
Instron energy fatigue, in	-260.5	101.7(51.3)	0.50	25.2	28.6	35.7	71.4
cross	247.0	97.58(62.9)	0.41	21.3	42.9	50.0	71.4
total	-864.0	100.5(34.4)	0.64	19.5	35.7	57.1	78.6

[a]Parentheses: Standard error of slope.
[b]Based on observed value as reference.

TABLE X

LINEAR RELATIONSHIPS BETWEEN SACK PAPER PROPERTIES AND PROGRESSIVE HEIGHT FACE DROP IN SAFE INCHES

Combined Studies — 32 Regular and 14 Extensible Samples

Variable	Regression Constants Intercept	Regression Constants Slope[a]	Correlation Coefficient	Av. Diff., %[b]	Per Cent of Comparisons Within ±10%	±15%	±25%
Weight	-476.4	19.48(37.6)	0.08	46.6	15.2	23.9	37.0
Caliper	607.0	-14.92(66.7)	-0.03	46.6	15.2	23.9	34.8
Apparent density	342.9	19.73(46.8)	0.06	46.4	17.4	23.9	32.6
Bursting strength	-717.3	30.30(6.86)	0.55	37.5	19.6	30.4	37.0
Bursting strength factor	-660.0	1480(352)	0.54	37.8	17.4	32.6	39.1
Tearing strength, in	110.2	3.337(4.38)	0.11	46.5	13.0	28.3	30.4
cross	-783.9	9.529(2.46)	0.50	40.9	10.9	21.7	39.1
combined	-897.4	5.448(1.85)	0.41	43.1	15.2	23.9	37.0
Tensile, in	1467.5	-31.72(4.28)	-0.74	33.1	13.0	23.9	45.7
cross	1262.4	-40.53(15.2)	-0.37	39.7	23.9	34.8	50.0
combined	1715.4	-24.82(3.59)	-0.72	33.1	13.0	28.3	47.8
Stretch, in	283.5	61.24(5.81)	0.85	24.9	15.2	39.1	65.2
cross	-259.1	198.8(34.3)	0.66	30.8	23.9	34.8	45.7
combined	88.6	55.40(4.59)	0.88	20.3	28.3	41.3	76.1
T.E.A., in	199.3	521.5(49.5)	0.85	23.9	28.3	43.5	63.0
cross	-211.4	1391(318)	0.55	35.0	19.6	30.4	47.8
combined	-45.6	495.3(38.7)	0.89	18.4	41.3	65.2	73.9
Frag, in	-131.9	1.344(0.117)	0.87	22.8	37.0	43.5	67.4
cross	609.4	-0.1675(0.325)	-0.08	46.6	19.6	19.6	37.0
combined	-353.3	0.8674(0.143)	0.67	28.0	15.2	32.6	54.3
Impulse, in	145.8	29.44(2.78)	0.85	24.0	28.3	45.7	65.2
cross	-275.2	90.83(21.5)	0.54	35.9	26.1	30.4	43.5
combined	-70.4	27.48(2.35)	0.87	20.2	30.4	50.0	69.6
T.A. impact fatigue	115.2	13.31(0.79)	0.93	16.7	37.0	58.7	76.1
Porosity	488.4	2.838(4.76)	0.09	46.6	17.4	21.7	37.0
Scattering coefficient	1902.1	-5.600(2.10)	-0.37	44.3	15.2	17.4	28.3

[a]Parentheses: Standard error of slope.
[b]Based on observed value as reference.

TABLE XI

LINEAR RELATIONSHIPS BETWEEN SACK PAPER PROPERTIES AND PROGRESSIVE HEIGHT FACE DROP IN SAFE DROPS

Study I – 20 Regular Kraft Samples

Variable	Regression Constants[a] Intercept	Slope	Correlation Coefficient	Av. Diff., %[b]	Per Cent of Comparisons Within ±10%	±15%	±25%
Weight	36.7	-0.555(0.31)	-0.39	14.8	45.0	60.0	85.0
Caliper	7.2	0.213(0.77)	0.06	15.2	40.0	55.0	90.0
Apparent density	10.8	-0.260(0.41)	-0.15	15.0	45.0	60.0	90.0
Bursting strength	7.9	0.0120(0.084)	0.03	15.2	40.0	60.0	90.0
Bursting strength factor	6.8	2.04(4.2)	0.11	14.8	40.0	60.0	85.0
Tearing strength, in	11.5	-0.0254(0.036)	-0.17	14.9	55.0	60.0	85.0
cross	9.3	-0.0070(0.031)	-0.05	15.4	45.0	55.0	90.0
combined	11.3	-0.0115(0.020)	-0.14	15.3	50.0	60.0	85.0
Tensile, in	8.3	0.0018(0.14)	0.00	15.3	40.0	55.0	90.0
cross	12.4	-0.2117(0.13)	-0.35	13.9	55.0	65.0	95.0
combined	14.4	-0.114(0.10)	-0.26	15.5	30.0	60.0	90.0
Stretch, in	5.2	1.91(1.5)	0.30	13.6	60.0	60.0	90.0
cross	5.1	0.844(0.31)	0.54	12.9	40.0	75.0	90.0
combined	3.3	0.927(0.29)	0.60	11.9	45.0	75.0	90.0
T.E.A., in	6.8	4.39(4.8)	0.21	14.1	60.0	60.0	85.0
cross	5.1	6.06(2.7)	0.47	13.6	50.0	65.0	90.0
combined	3.1	5.91(2.2)	0.53	11.7	60.0	75.0	90.0
Frag, in	6.3	0.00495(0.0035)	0.31	13.7	55.0	60.0	80.0
cross	5.2	0.00529(0.0024)	0.47	12.5	65.0	75.0	90.0
combined	4.9	0.00341(0.0016)	0.45	12.0	60.0	70.0	90.0
Impulse, in	5.5	0.338(0.24)	0.32	13.2	55.0	60.0	85.0
cross	5.4	0.322(0.20)	0.36	14.0	50.0	60.0	90.0
combined	2.5	0.338(0.14)	0.49	11.8	60.0	65.0	85.0
T.A. impact fatigue	5.1	0.143(0.035)	0.70	10.9	55.0	75.0	90.0
Porosity	8.7	-0.0291(0.030)	-0.22	14.5	40.0	60.0	90.0
Scattering coefficient	13.8	-0.0222(0.015)	-0.33	14.3	50.0	65.0	85.0
Van der Korput energy, in	6.8	0.793(0.81)	0.23	14.0	60.0	60.0	85.0
cross	5.3	1.202(0.59)	0.43	13.8	40.0	65.0	90.0
combined	3.5	1.086(0.46)	0.49	11.7	65.0	70.0	85.0
High-speed tensile, in	8.7	-0.0118(0.22)	-0.01	15.4	40.0	55.0	90.0
cross	11.9	-0.1994(0.15)	-0.29	14.7	40.0	65.0	95.0
combined	14.6	-0.1352(0.13)	-0.25	15.6	30.0	55.0	90.0
High-speed stretch, in	4.2	2.491(1.67)	0.33	13.3	60.0	60.0	90.0
cross	5.0	0.988(0.42)	0.48	13.6	40.0	65.0	90.0
combined	2.4	1.195(0.40)	0.58	12.2	45.0	65.0	90.0
High-speed work, in	5.6	7.725(6.01)	0.29	13.2	60.0	60.0	85.0
cross	5.1	6.369(3.28)	0.42	14.0	50.0	60.0	85.0
combined	2.3	7.016(2.74)	0.52	12.2	60.0	70.0	90.0

[a]Parentheses: Standard error of slope.

[b]Based on observed value as reference.

TABLE XII

LINEAR RELATIONSHIPS BETWEEN SACK PAPER PROPERTIES AND PROGRESSIVE HEIGHT FACE DROP IN SAFE DROPS

Study II – 12 Regular Samples

Variable	Regression Constants		Correlation Coefficient	Av. Diff., %[b]	Per Cent of Comparisons Within		
	Intercept	Slope[a]			±10%	±15%	±25%
Weight	-17.9	0.489(0.40)	0.36	11.1	58.3	75.0	83.3
Caliper	-0.4	1.232(0.65)	0.51	10.8	66.7	75.0	83.3
Apparent density	14.6	-0.888(0.48)	-0.50	10.8	58.3	75.0	83.3
Bursting strength	0.5	0.170(0.086)	0.53	11.3	58.3	75.0	91.7
Bursting strength factor	1.3	7.623(4.5)	0.47	12.4	50.0	66.7	91.7
Tearing strength, in	6.3	0.0065(0.034)	0.06	13.8	50.0	75.0	83.3
cross	7.4	-0.0026(0.0537)	-0.02	14.0	41.7	58.3	83.3
combined	6.5	0.0022(0.0213)	0.03	13.9	50.0	58.3	83.3
Tensile, in	3.1	0.117(0.11)	0.32	12.9	41.7	58.3	91.7
cross	5.5	0.080(0.20)	0.13	13.9	41.7	58.3	91.7
combined	2.3	0.0902(0.087)	0.31	13.2	33.3	66.7	91.7
Stretch, in	-0.9	5.257(1.8)	0.69	10.2	58.3	66.7	100.0
cross	2.0	1.506(0.49)	0.70	10.7	41.7	83.3	100.0
combined	-0.6	1.578(0.36)	0.81	9.0	41.7	100.0	100.0
T.E.A., in	2.1	14.95(5.3)	0.66	9.6	66.7	83.3	91.7
cross	2.5	9.673(3.2)	0.69	10.4	58.3	83.3	100.0
combined	0.1	8.800(1.8)	0.83	7.7	66.7	91.7	100.0
Frag, in	4.4	0.00688(0.0031)	0.57	11.4	58.3	66.7	91.7
cross	2.1	0.0103(0.0024)	0.81	8.0	58.3	91.7	100.0
combined	2.5	0.00532(0.0014)	0.73	8.2	66.7	83.3	100.0
Impulse, in	0.2	0.889(0.40)	0.57	11.3	58.3	75.0	91.7
cross	0.5	0.888(0.32)	0.66	11.1	50.0	66.7	100.0
combined	-3.5	0.700(0.18)	0.78	8.4	58.3	83.3	100.0
T.A. impact fatigue	5.3	0.110(0.035)	0.70	9.7	66.7	75.0	91.7
Porosity	6.2	0.0967(0.082)	0.35	12.7	50.0	66.7	83.3
Scattering coefficient	12.8	-0.023(0.033)	-0.21	14.3	41.7	58.3	91.7
Zero-span tensile, in	0.7	0.0894(0.080)	0.33	12.9	41.7	58.3	91.7
cross	11.1	-0.0705(0.15)	-0.15	13.8	50.0	50.0	83.3
combined	-0.1	0.0556(0.076)	0.23	13.4	41.7	75.0	75.0
Zero-span fiber stress	1.1	0.105(0.18)	0.18	14.2	50.0	66.7	83.3
M.I.T. fold, in	5.9	0.0024(0.0028)	0.26	13.1	50.0	75.0	75.0
cross	5.6	0.0033(0.0037)	0.27	12.5	50.0	75.0	75.0
Instron strain fatigue, in	4.8	0.601(0.68)	0.27	13.1	58.3	75.0	83.3
cross	1.4	1.260(0.44)	0.67	11.1	33.3	75.0	100.0
total	-0.4	0.899(0.33)	0.66	10.8	41.7	75.0	91.7
Instron energy fatigue, in	4.3	0.483(0.22)	0.57	11.7	50.0	83.0	100.0
cross	2.3	0.871(0.32)	0.66	9.9	50.0	100.0	100.0
total	1.9	0.468(0.13)	0.74	8.9	58.3	83.3	100.0

[a]Parentheses: Standard error of slope.
[b]Based on observed value as reference.

TABLE XIII

LINEAR RELATIONSHIPS BETWEEN SACK PAPER PROPERTIES AND PROGRESSIVE HEIGHT FACE DROP IN SAFE DROPS

Study II – 14 Extensible Samples

Variable	Regression Constants: Intercept	Regression Constants: Slope[a]	Correlation Coefficient	Av. Diff., %[b]	Per Cent of Comparisons Within: ±10%	±15%	±25%
Weight	7.8	0.104(0.54)	0.06	15.3	42.9	57.1	85.7
Caliper	14.2	-0.176(0.89)	-0.06	15.3	42.9	57.1	85.7
Apparent density	11.0	0.245(0.80)	0.09	15.4	42.9	57.1	78.6
Bursting strength	9.6	0.0797(0.16)	0.14	15.6	35.7	64.3	92.9
Bursting strength factor	10.6	2.958(7.7)	0.11	15.5	42.9	64.3	85.7
Tearing strength, in	-6.6	0.160(0.090)	0.46	13.8	42.9	71.4	78.6
cross	16.1	-0.0189(0.053)	-0.10	14.9	42.9	64.3	78.6
combined	9.6	0.0131(0.038)	0.10	15.5	35.7	57.1	92.9
Tensile, in	19.2	-0.285(0.28)	-0.28	14.8	35.7	57.1	85.7
cross	4.0	0.565(0.32)	0.45	12.8	42.9	57.1	85.7
combined	10.9	0.0608(0.24)	0.07	15.3	42.9	57.1	85.7
Stretch, in	7.7	0.599(0.30)	0.50	14.1	28.6	71.4	85.7
cross	3.3	2.13(1.3)	0.42	14.1	42.9	71.4	78.6
combined	4.4	0.639(0.27)	0.56	13.4	35.7	78.6	85.7
T.E.A., in	6.0	5.762(3.1)	0.47	14.7	35.7	71.4	78.6
cross	2.9	17.9(6.3)	0.64	12.3	42.9	71.4	85.7
combined	1.3	6.52(2.3)	0.63	12.6	64.3	78.6	85.7
Frag, in	1.2	0.0172(0.0035)	0.82	8.5	64.3	85.7	100.0
cross	8.1	0.0113(0.0089)	0.34	15.3	42.9	64.3	92.9
combined	1.3	0.0104(0.0029)	0.72	10.8	57.1	78.6	92.9
Impulse, in	7.5	0.241(0.13)	0.48	14.7	42.9	71.4	85.7
cross	1.9	1.184(0.48)	0.58	13.3	42.9	71.4	85.7
combined	5.6	0.229(0.11)	0.53	14.2	50.0	71.4	85.7
T.A. impact fatigue	5.4	0.144(0.029)	0.82	8.8	57.1	85.7	100.0
Porosity	11.6	0.130(0.11)	0.32	14.8	35.7	57.1	78.6
Scattering coefficient	43.8	-0.125(0.017)	-0.91	6.2	85.7	100.0	100.0
Zero-span tensile, in	33.7	-0.383(0.094)	-0.76	10.0	57.1	71.4	92.9
cross	9.7	0.0693(0.17)	0.12	15.3	42.9	57.1	92.9
combined	34.7	-0.206(0.098)	-0.52	13.4	50.0	64.3	78.6
Zero-span fiber stress	32.2	-0.415(0.21)	-0.49	12.9	50.0	71.4	78.6
M.I.T. fold, in	8.8	0.00641(0.0035)	0.47	14.1	42.9	71.4	85.7
cross	6.6	0.0171(0.0046)	0.73	9.2	50.0	85.7	92.9
Instron strain fatigue, in	2.6	0.779(0.31)	0.58	13.7	42.9	64.3	85.7
cross	4.8	1.413(1.11)	0.34	14.1	42.9	64.3	92.9
total	-2.3	0.792(0.27)	0.64	12.9	42.9	64.3	92.9
Instron energy fatigue, in	2.3	1.006(--)	0.50	14.6	35.7	71.4	85.7
cross	7.6	0.921(--)	0.39	12.9	50.0	71.4	78.6
total	-3.4	0.975(0.34)	0.63	11.8	64.3	78.6	85.7

[a]Parentheses: Standard error of slope.
[b]Based on observed value as reference.

TABLE XIV

LINEAR RELATIONSHIPS BETWEEN SACK PAPER PROPERTIES AND PROGRESSIVE HEIGHT FACE DROP IN SAFE DROPS

Combined Studies — 32 Regular and 14 Extensible Samples

Variable	Regression Constants: Intercept	Regression Constants: Slope[a]	Correlation Coefficient	Av. Diff., %[b]	Per Cent of Comparisons Within ±10%	±15%	±25%
Weight	-2.3	0.229(0.43)	0.08	27.0	21.7	37.0	47.8
Caliper	10.3	-0.146(0.76)	-0.03	27.0	21.7	39.1	52.2
Apparent density	7.6	0.207(0.54)	0.06	26.9	26.1	34.8	54.3
Bursting strength	-4.7	0.347(0.078)	0.55	22.2	28.3	37.0	67.4
Bursting strength factor	-4.1	16.95(4.0)	0.54	22.4	28.3	41.3	67.4
Tearing strength, in	5.3	0.0339(0.050)	0.10	27.0	19.6	37.0	47.8
cross	-5.8	0.1116(0.028)	0.52	23.8	15.2	39.1	63.0
combined	23.3	-0.287(0.040)	-0.73	19.6	30.4	47.8	78.2
Tensile, in	20.3	-0.363(0.049)	-0.75	19.6	30.4	43.5	73.9
cross	18.5	-0.495(0.17)	-0.40	22.6	37.0	47.8	56.5
combined	-6.9	0.0627(0.0211)	0.41	25.0	21.7	41.3	56.5
Stretch, in	6.8	0.699(6.7)	0.85	15.4	37.0	63.0	82.6
cross	0.2	2.365(0.38)	0.69	18.2	39.1	43.5	73.9
combined	4.5	0.637(5.1)	0.88	12.9	45.7	73.9	87.0
T.E.A., in	5.8	5.975(0.56)	0.85	15.0	45.7	63.0	84.8
cross	0.9	16.27(3.6)	0.56	21.1	30.4	45.7	65.2
combined	3.0	5.691(0.43)	0.89	11.6	63.0	76.1	84.8
Frag, in	2.1	0.0152(0.0014)	0.86	13.5	50.0	69.6	87.0
cross	10.1	-0.0013(0.0037)	-0.05	27.0	23.9	39.1	47.8
combined	-0.7	0.0101(0.0016)	0.68	16.7	32.6	58.7	84.8
Impulse, in	5.2	0.336(0.0318)	0.85	14.8	45.7	58.7	84.8
cross	0.03	1.077(0.24)	0.56	21.4	30.4	45.7	60.9
combined	2.7	0.315(2.6)	0.87	12.6	47.8	69.6	91.3
T.A. impact fatigue	4.8	0.152(0.0089)	0.93	10.1	54.3	78.3	93.5
Porosity	9.1	0.0286(0.054)	0.08	27.1	21.7	39.1	50.0
Scattering coefficient	24.7	-0.0619(0.024)	-0.36	26.4	19.6	28.3	50.0

[a] Parentheses: Standard error of slope.
[b] Based on observed value as reference.

TABLE XV

COMPARATIVE RANKING OF SACK PAPER TESTS BASED ON FACE DROP PREDICTIVE ABILITY FOR THE REGULAR KRAFT SACKS OF STUDY I

	Test Property		Correlation Coefficient		Av. Prediction Diff., %[c]
					21.1[d]
1.	T.A. impact fatigue		0.72[b]		16.7
2.	T.E.A., combined		0.53[a]		18.7
3.	Impulse, combined		0.49[a]		18.7
4.	Van der Korput, combined		0.49[a]	omitted	18.8
5.	Frag, combined		0.48[a]		18.9
6.	Stretch, combined		0.59[b]		19.0
7.	High-speed stretch, combined	SM	0.56[b]		19.6
8.	High-speed work, combined	WV	0.52[a]		19.6
9.	Frag, cross		0.47[a]		19.8
10.	Stretch, cross		0.53[a]		20.9
11.	High-speed work, in		0.31		20.9
12.	Impulse, in		0.34		21.0
13.	High-speed stretch, in		0.34		21.0
14.	T.E.A., cross		0.47[a]		21.7
15.	Stretch, in		0.30		21.8
16.	Frag, in		0.34		21.9
17.	High-speed stretch, cross	SL	0.47[a]		22.0
18.	Van der Korput, cross		0.42		22.2
19.	High-speed work, cross		0.41		22.5
20.	Van der Korput, in		0.24		22.5
21.	Impulse, cross		0.35		22.5
22.	Tensile, cross		-0.34		22.6
23.	Scattering coefficient		-0.33		22.6
24.	T.E.A., in		0.22		22.7
25.	Porosity		-0.21		23.6
26.	Weight		-0.40		23.8
27.	Burst factor		0.14		23.8
28.	High-speed tensile, cross		-0.28		23.9
29.	Tear, in		-0.17		24.0
30.	Apparent density		-0.13		24.2
31.	Bursting strength		0.06		24.4
32.	Tensile, in		0.04		24.5
33.	Caliper		0.05		24.6
34.	Tear, combined		-0.14		24.7
35.	High-speed tensile, in		0.01		24.7
36.	Tear, cross		-0.06		25.0
37.	Tensile, combined		-0.22		25.0
38.	High-speed tensile, combined		-0.22		25.1

[a]Significant at 05 level. [b]Significant at 01 level.

[c]The average difference between computed and observed progressive height face drop values in safe inches.

[d]Average percentage difference of face drop values about their own average.

TABLE XVI

COMPARATIVE RANKING OF SACK PAPER TESTS BASED ON FACE DROP PREDICTIVE ABILITY FOR THE REGULAR KRAFT SACKS OF STUDY II

	Test Property			Correlation Coefficient	Av. Prediction Diff., %[c]
					20.9[d]
1.	T.E.A., combined		2	0.83[b]	12.3
2.	Stretch, combined		1	0.85[b]	12.5
3.	Frag, cross		3	0.80[b]	12.5
4.	Frag, combined		5	0.76[b]	12.6
5.	Impulse, combined		4	0.79[b]	13.0
6.	Energy fatigue, combined	MT	8	0.70[a]	14.7
7.	T.A. impact fatigue		11	~~0.69[a]~~	~~15.2~~
8.	T.E.A., cross		9	0.70[a]	15.4
9.	T.E.A., in			0.65[a]	15.7
10.	Stretch, cross		6	0.75[b]	15.8
11.	Stretch, in.			0.68[a]	16.0
12.	Strain fatigue, cross	NC	7	0.71[b]	16.6
13.	Energy fatigue, cross	MC		0.59[a]	16.6
14.	Strain fatigue, combined			0.68[a]	16.7
15.	Caliper			0.32	17.0
16.	Impulse, cross			0.70[a]	17.1
17.	Frag, in			0.56[a]	17.2
18.	Bursting strength			0.50	17.3
19.	Strain fatigue, in			0.26	17.5
20.	Impulse, in			0.55	17.6
21.	Apparent density			-0.53	17.7
22.	Weight			0.32	18.3
23.	Burst factor			0.45	18.7
24.	Porosity			0.35	19.1
25.	Fold, cross			0.25	19.5
26.	Fold, in			0.28	20.0
27.	Zero span, in			0.30	20.1
28.	Strain fatigue, in			0.26	20.3
29.	Tensile, in			0.29	20.9
30.	Zero span, combined			0.19	21.0
31.	Tensile, combined			0.25	21.3
32.	Tear, in			0.11	21.7
33.	Tear, combined			0.08	21.8
34.	Tear, cross			0.02	22.1
35.	Zero-span fiber stress			0.18	22.1
36.	Zero span, cross			-0.16	22.2
37.	Tensile, cross			0.05	22.2
38.	Scattering coefficient			-0.16	22.6

[a] Significant at 05 level. [b] Significant at 01 level.
[c] The average difference between computed and observed progressive height face drop values in safe inches.
[d] Average percentage differences of face drop values about their own average.

TABLE XVII

COMPARATIVE RANKING OF SACK PAPER TESTS BASED ON FACE DROP PREDICTIVE ABILITY FOR THE EXTENSIBLE KRAFT SACKS OF STUDY II

	Test Property		Correlation Coefficient	Av. Prediction Diff., %[c]
				23.1[d]
1.	Scattering coefficient	1	-0.91[b]	9.7
2.	Frag, in	2	0.83[b]	13.5
3.	Fold, cross	5	0.74[b]	14.7
4.	T.A. impact fatigue	3	0.82[b]	15.1
5.	Zero span, in	4	-0.77[b]	17.0
6.	Frag, combined	6	0.74[b]	17.6
7.	Energy fatigue, combined	7	0.64[a]	19.5
8.	T.E.A., cross		0.66[b]	20.0
9.	Tensile, cross		0.48	20.9
10.	Energy fatigue, cross		0.41	21.3
11.	T.E.A., combined	8	0.63[a]	21.6
12.	Impulse, cross		0.58[a]	22.0
13.	Strain fatigue, combined	9	0.62[a]	22.0
14.	Zero-span fiber stress		-0.47	22.5
15.	Stretch, combined		0.55[a]	23.1
16.	Zero span, combined		-0.51	23.1
17.	Strain fatigue, in		0.56[a]	23.2
18.	Tear, in.		0.42	23.5
19.	Stretch, cross		0.43	23.7
20.	Strain fatigue, cross		0.36	24.0
21.	Impulse, combined	10	0.52	24.4
22.	Stretch, in		0.48	24.4
23.	Fold, in		0.45	24.5
24.	T.E.A., in		0.46	25.2
25.	Energy fatigue, in		0.50	25.2
26.	Impulse, in		0.46	25.3
27.	Tear, cross		-0.13	25.3
28.	Frag, cross		0.36	25.6
29.	Tensile, in		-0.26	25.6
30.	Porosity		0.33	25.7
31.	Zero span, cross		0.14	26.1
32.	Tensile, combined		0.11	26.1
33.	Caliper		-0.07	26.3
34.	Weight		0.04	26.4
35.	Burst factor		0.14	26.4
36.	Apparent density		0.10	26.5
37.	Bursting strength		0.17	26.5
38.	Tear, combined		0.07	26.8

[a] Significant at 05 level. [b] Significant at 01 level.
[c] The average difference between computed and observed progressive height face drop values in safe inches.
[d] Average percentage difference of face drop values about their own average.

TABLE XVIII

COMPARATIVE RANKING OF SACK PAPER PROPERTIES BASED ON FACE DROP PREDICTIVE ABILITY FOR THE COMBINED REGULAR AND EXTENSIBLE DATA OF STUDIES I AND II

	Test Property	Correlation Coefficient	Av. Prediction Diff., %[b]
			29.9[c]
1.	T.A. impact fatigue	0.93[a]	16.7
2.	T.E.A., combined	0.89[a]	18.4
3.	Impulse, combined	0.87[a]	20.2
4.	Stretch, combined	0.88[a]	20.3
5.	Frag, in	0.87[a]	22.8
6.	T.E.A., in	0.85[a]	23.9
7.	Impulse, in	0.85[a]	24.0
8.	Stretch, in	0.85[a]	24.9
9.	Frag, combined	0.67[a]	28.0
10.	Stretch, cross	0.66[a]	30.8
11.	Tensile, in	-0.74[a]	33.1
12.	Tensile, combined	-0.72[a]	33.1
13.	T.E.A., cross	0.55[a]	35.0
14.	Impulse, cross	0.54[a]	35.9
15.	Bursting strength	0.55[a]	37.5
16.	Burst factor	0.54[a]	37.8
17.	Tensile, cross	-0.37[a]	39.7
18.	Tear, cross	0.50[a]	40.9
19.	Tear, combined	0.41[a]	43.1
20.	Scattering coefficient	-0.37[a]	44.3
21.	Apparent density	0.06	46.4
22.	Tear, in	0.11	46.5
23.	Frag, cross	-0.08	46.6
24.	Weight	0.08	46.6
25.	Caliper	-0.03	46.6
26.	Porosity	0.09	46.6

[a]Significant at the 01 level.

[b]The average difference between computed and observed face drop values in safe inches.

[c]Average percentage difference of face drop values about their own average.

LITERATURE CITED

1. Progress Report Twelve, February 8, 1960.

2. Progress Report Twenty-One, October 1, 1962.

3. Progress Report Twenty-Six, November 6, 1962.

4. Progress Report Five, February 5, 1959.

5. Cooper, T. G., Fourteenth TAPPI Testing Conference, New Orleans, November, 1963.

THE INSTITUTE OF PAPER CHEMISTRY

William J. Whitsitt

William J. Whitsitt, Research Aide

R. C. McKee

R. C. McKee, Senior Research Associate
Chairman, Container Section